THE RELATION OF HAIRY LEAF COVERINGS TO THE RESISTANCE OF LEAVES TO TRANSPIRATION.*†

J. D. SAYRE.

INTRODUCTION.

A great many of our common plants have hair-like structures on their leaf surfaces. These epidermal hairs can readily be divided into two classes; those that contain protoplasm, and sometimes chlorophyll, which are called glandular hairs; and those that are dead, and are filled with air.

It is obvious that the first kind of hairs add to the evaporating surface of the leaf, but there is some doubt as to the effect which dead air-containing hairs have on the water loss from leaves. The following paper deals only with the dead air-containing hairs. There are several different forms of these hairs: (a) Unicellular structures perpendicular to the leaf surface; (b) One or more celled structures lying parallel with the leaf surface; (c) Unbranched, many-celled structures, extending more or less parallel to the leaf surface; (d) Many celled structures, much branched, having the branches both parallel and perpendicular to the leaf surface.

The mullein plant (*Verbascum thapsus*) which was used in the following experiments, is covered with hairs of the last named type. Of all the plants found in this locality it has the densest covering of hairs. The experimentation involved the obtaining of continuous records of the common environmental factors influencing plant processes, with records of the water loss from the plants.

HISTORICAL.

Statements have been made by various authors as to the relation of hairs to transpiration, but these assertions do not seem to have been founded on experimentation.

Warming (1) says: "It is evident that transpiring will be very materially reduced when the transpiring surface is clothed by air-containing bodies, in and between which the air is so firmly lodged that its circulation is obstructed."

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Jost (2) seems to consider hairs as effective in retarding air currents near the surface of the leaf: "Development of hairs full of air can also effectively retard transpiration, since such a covering protects the plant from the effects of air currents, producing a superficial region free from atmospheric movements."

Gager (3) gives practically the same statement: "Certain structural features of the plant operate to reduce transpiration. The epidermal hairs, as for example on mullein leaves, tend to retain the more humid air near the surface of the leaf, even when the wind blows."

Cowles, in his text book (4) gives a somewhat different aspect given to the whole matter: "Hairs commonly are believed to have an important role in the retardation of transpiration, but the evidence for this view is not abundant. Probably they are much inferior in this respect to cutin or even waxy coats. Wooly felt would seem to be most efficient. Removal of hairs in *Stachys lanata* results in an increase of 20% to 50% in transpiration. Evaporating surfaces covered with hairy felt have been shown to lose much less water than without the hairy coverings. Similar effects might be looked for in scale covered leaves or leaves with branched hairs, when the hairy coat is dense enough to retard water vapor. In most plants that are hairy, however, the hairs are erect and more or less scattered, so it is difficult to see how they can appreciably retard water vapor, though their presence may reduce the evaporating surface. It must be admitted that the known uses of leaf hairs are small in comparison with their abundant development. While the discovery of advantages now unknown is possible, it is much more likely that most of such hairs are of little or no advantage to the plant."

Little actual experimentation has been done on the relation of hairy coverings to transpiration. Wiegand (5) sums up this experimentation in his paper with the results of his own experiments. "Kerner (6) took two raspberry leaves and covered the bulbs of two thermometers with them, having the hairy side outermost in one and the smooth side in the other; the smooth one showed 2-5° F. higher than the other, which would indicate increased transpiration. Vesque (7) found by cultural experiments that with certain plants, when dryness

increased, hairy coverings increased in density also. Brenner (8) found that in certain species of Quercus hairy coverings became thicker when exposed to greater intensity of sunlight." Wiegand gives the following statements concerning his own work:

"It is quite generally recognized that by far the most important factor in transpiration is evaporation; indeed, we may say that transpiration is really evaporation modified and regulated by the plant. Therefore, it seems that a study of the relation of hairy coverings to evaporation would throw much light on the subject of transpiration. Good quality blotting paper was used as the evaporating surface. The loss of water was determined by weighing. Cotton made waterproof by paraffin in gasoline, was used for the protective covering and an electric fan was used to produce wind." He draws the following general conclusions from his experimentation. "The evaporation experiments tend to show that porous coverings like cotton, wool, or hair must be very thick to produce any appreciable effect in retarding evaporation if the surrounding atmosphere is quiet, but become very efficient even in thin layers when the air is in motion. It seems probable that those plants that live in situations where a moderate water supply is available, but there transpiration must be reduced in excessively dry times, but not interfered with when the surrounding air is damp and transpiration therefore difficult employ a hairy covering to retard transpiration."

These conclusions were drawn from evaporation experiments in which cotton, wool and hair were used for protective coverings, and the water loss from a standard evaporating surface was measured. It is quite definitely known that very little water is lost from the cuticular surface of a leaf as compared with the internal surface, and while it is obvious that cotton, wool, or hair would produce those effects on a standard evaporating surface, it does not mean that the water vapor from the internal surfaces of the leaf would be retarded by these coverings.

In conclusion it may be said that very little critical experimentation has been done on the relation of hairy coverings to transpiration. The general opinion is that leaves with hairy coverings have a greater resistance to water loss in bright sunshine and in wind than leaves without these coverings.

EXPERIMENTAL METHODS.

The experiments summarized in this paper were performed under the direction of Dr. E. N. Transeau, at the Ohio State University in the research room of the Botanical Greenhouse and in a darkroom adjoining the Plant Physiology laboratory. The apparatus, with some alterations, which was used has been described by Transeau (9).

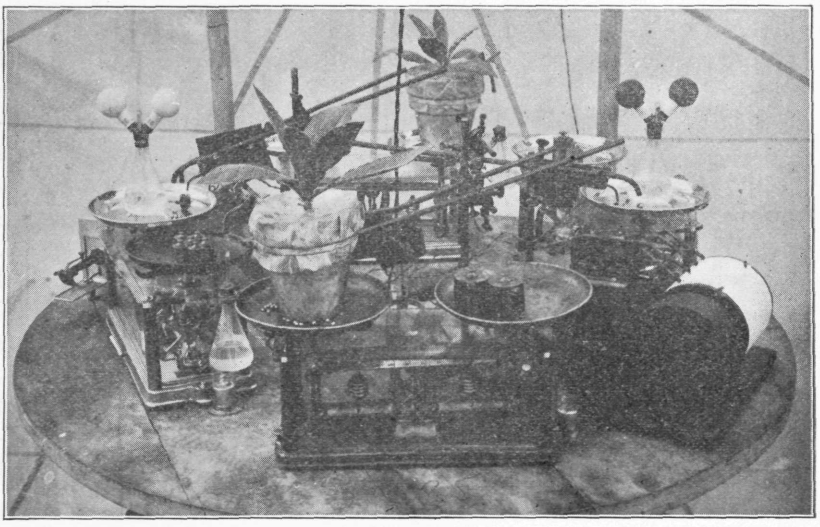

FIG. 1.

Rotating table with the apparatus and plants arranged on it. The table was turned at a very slow rate during the experiments.

In each of the experiments continuous, simultaneous, records of the following factors were secured for a period of 24 hours or more; temperature, humidity, duration of sunshine, intensity of sunshine (as shown by the increased evaporation from a black atmometer compared with that from a white atmometer), evaporation from a white atmometer cup, transpiration from one or more plants, and wind velocity. The temperature was recorded in degrees, Fahrenheit, and the humidity in percentages of saturation, on a combined hygrothermograph, which was checked up from time to time with a standard sling psychrometer and corrected if necessary. A record of the duration of sunshine for the days on which

experiments were performed in the greenhouse was obtained from the U. S. Weather Bureau Station, Columbus, Ohio. This record is expressed in percentages of possible sunshine per hour. No record of wind velocity was kept except in the experiments when an electric fan was used to produce air currents. Then a U. S. Weather Bureau anemometer was used and the velocity is expressed in miles per hour.

FIG. 2.
One of the plants used in the experiments, showing the method of sealing and irrigating the pot.

The evaporation and transpiration records were determined as described by Transeau by replacing the loss of weight of a plant or atmometer, which is balanced on one pan of a balance, by dropping steel shot each weighing a gram on the pan beside the plant and recording the number of shot required to keep the plant balanced, with the time interval between shot.

This is done automatically by the shot dropping tubes and chronograph designed by Transeau. A plant or atmometer is placed on a pan of the balance, which is prevented from vibrating in wind or by a slight jar with a mercury cup and piston attached to one beam, and balanced by an equal weight placed on the opposite pan. When the loss of weight causes the pan to rise to a certain height an electric circuit is closed which operates the shot dropper and the pen on the chronograph. The pen makes a straight line on the drum, which is revolved by a clock at a known rate, except when the electric circuit is closed. From these results (the number of shot and the time interval between each) the rate of water loss in grams per hour is calculated. This apparatus, which can be used to take six or more records at one time, affords a very satisfactory method of determining comparative transpiration rates.

In obtaining the evaporation data, standardized white spherical cups were used. The evaporation from blackened cups was also measured by using spherical cups, covered with washed carbon. The white cups, because of the method of using them, were standardized with a new cup mounted on a standard non-absorbing mounting, and the black cups were standardized with the two white cups.

TABLE I.

STANDARDIZATION OF WHITE CUPS WITHOUT MERCURY VALVES WITH A NEW CUP MOUNTED ON STANDARD MOUNTING WITH MERCURY VALVES.

Cup No.	16–161	16–211	16–225	16–201
Total evaporation, grams. (12 days).....	268.5	273.1	269.1	285.8
Coefficient, old.....	.95	.92	.95	.96
Coefficient, new.....	1.02	1.00	1.01	.96

Cup 16–201—.96 (New) taken as standard.

TABLE II.

STANDARDIZATION OF BLACK CARBON COVERED CUPS WITH RESTANDARDIZED WHITE CUPS.

	White Cups, Coe.		Black Cups, Coe.	
	16–161	1.02	16–307	.92
	16–211	1.01	16–375	.93
Total evaporation, grams. (10 days).....	272.7		365.6	
Total evaporation, grams. (10 nights)....	103.8		103.5	
Coefficients.....	1.01		1.01	

The transpiration rate was determined from plants, (Fig. 2), which were growing in six inch pots at the time they were used. In every experiment plants as nearly alike as possible in size and color were chosen. The potted plants were placed in six inch aluminum shells and sealed with paraffined cloth, cut to fit the top of the pot and shell, with a slit along the radius to a hole in the center for the plant stem. Small paraffined cloth washers were placed closely around the stem and carefully made air tight with warm paraffin. The six inch pots did not fit down in the shell, but rested on the edge, which left an air space between the bottom and sides of the pot and the shell. This space insured aeration of the soil as well as perfect drainage.

The matter of maintaining a uniform amount of moisture in the soil was at first done by watering the plants every 24 hours with as much water as they had lost during that time. Later porous cup irrigators were obtained which kept the soil in a six inch pot in perfect condition. The method of operating the irrigators was to seal a T-tube in the open end and fill it with water and insert it in a hole in the pot made by taking out a core of soil. A small piece of soft rubber hose was put on the straight end of the T-tube, with a pinch cock to close it and the arm of the T-tube was connected with a reservoir which was arranged so that the water level was below the pot.

In order to compare the transpiration rates of several different plants a very careful record of the leaf areas was kept and the transpiration from equal leaf areas was used. The leaves were measured by tracing their outlines on paper and measuring their total area with a planimeter which was adjusted to read in square centimeters. Leaf areas on every plant for every experiment were taken before the apparatus was started and as soon as the experiment was completed and as there was a considerable increase in leaf area for this length of time some method of taking an average had to be determined. By plotting the areas on cross section paper, using time as abscissæ and leaf area as ordinates, and assuming that the increase was a straight line between those two points, the area represented at noon was taken as the leaf area for that experiment. All results were reduced to the same area basis.

These experiments were performed in the research room of the greenhouse and in a dark room adjoining the Plant Physiology Laboratory. The dark room is light proof and has

no openings except into the halls of the building. While the framework of the greenhouse cast shadows on the plants and apparatus and produced unequal light conditions during the course of a day. In order to produce equal light conditions, the entire apparatus was arranged on a rotating table such as described by Livingston (10) in Plant World for use in standardizing porous cup atmometers (Fig. 1). The table was rotated by a small electric motor at a slow rate which was not fast enough to produce an increase in water loss, although it insured proper light and ventilation for the cups and plants.

The electric current for operating the shot droppers was taken from the electric light circuit in the greenhouse, and transformed by means of a bell ringer from 116 volts to 16 volts, which did away with the use of dry cells. The electrical connections for operating the recording and shot dropping apparatus were made by means of two wires hung from the roof of the greenhouse directly above the center of the table, into two concentric mercury cups. Small wires led from the mercury cups to the recording and shot dropping apparatus.

In order to properly ventilate the room where the experiments were performed and not to allow any direct air currents to blow on the apparatus, the table was placed in the center of the room and the ventilators directly above it were disconnected so that only those at the two ends of the room could be raised.

CALCULATION OF RESULTS.

The results of these experiments are expressed on an hourly basis. The time is recorded as hours, beginning with 1 for 1 A. M., and running up to 24 for 12 P. M., to correspond to the 24 hours of each day. The temperature which is taken from the thermographic record sheet, is the mean for each hour, and is expressed in degrees Fahrenheit. The humidity, taken in the same way, is recorded as saturation deficit (100%—humidity) and is expressed in percentages. The duration of sunshine record, which begins at sunrise and ends at sunset, was taken directly from the dial of the instrument, wind velocity the same way, and needed no alteration; but the hourly evaporation and transpiration rates had to be calculated.

Whenever the record sheet was taken from the drum of the chronograph, which turned at the rate of 12 millimeters per hour, the hour intervals were marked. The rate of water loss per hour was found by dividing the time interval (in millimeters) by the distance between shot marks. A table containing rate of water loss for all time intervals of 1 to 12 millimeters and distances between shot from 12 to 48 millimeters was made, and to obtain the hourly rate it was only necessary to measure the distance between shot marks and refer it to the table. The hourly evaporation rates are reduced to the rate of the Standard Cup by multiplying the chronographic rate by the coefficient of the cups. Tables I and II, on page 60, give these coefficients. The radio-evaporation is the difference between the Standard Cup and the black cups. The hourly transpiration rates are reduced to the rate of water loss from 100 square centimeters of leaf area, considering one surface of the leaf, by dividing the hourly chronographic rate by the leaf area.

All these calculations were aided very much by the use of an engineer's slide rule, an adding machine, and a planimeter.

EXPERIMENTS.

The object of these experiments was to determine the relation of the hairs on the mullein leaves to the resistance of the leaf to water loss. Two series of experiments were performed. In the first series a comparison of the transpiration rates of mullein and tobacco was made. Tobacco (*Nicotiana sp.*) was chosen as a suitable plant with which to compare mullein, because it is so nearly like mullein in every respect except the hairy covering. The thickness of the leaves, the arrangement of the intercellular structures as well as the general shape and appearance of the plant are as much alike as two plants of different families could possibly be. In the second series of experiments the transpiration rates of three different mullein plants were compared. At first, the normal plants were exposed to similar conditions and their comparative rates were determined; later, the hairs were removed from the lower side of one plant and from the upper side of another, while the third plant was left with hairs on both surfaces, and the rates under different conditions were compared. The removal of the hairs caused no injury to the leaf surfaces as the leaves kept on growing as healthily as ever and a microscopic examination of the

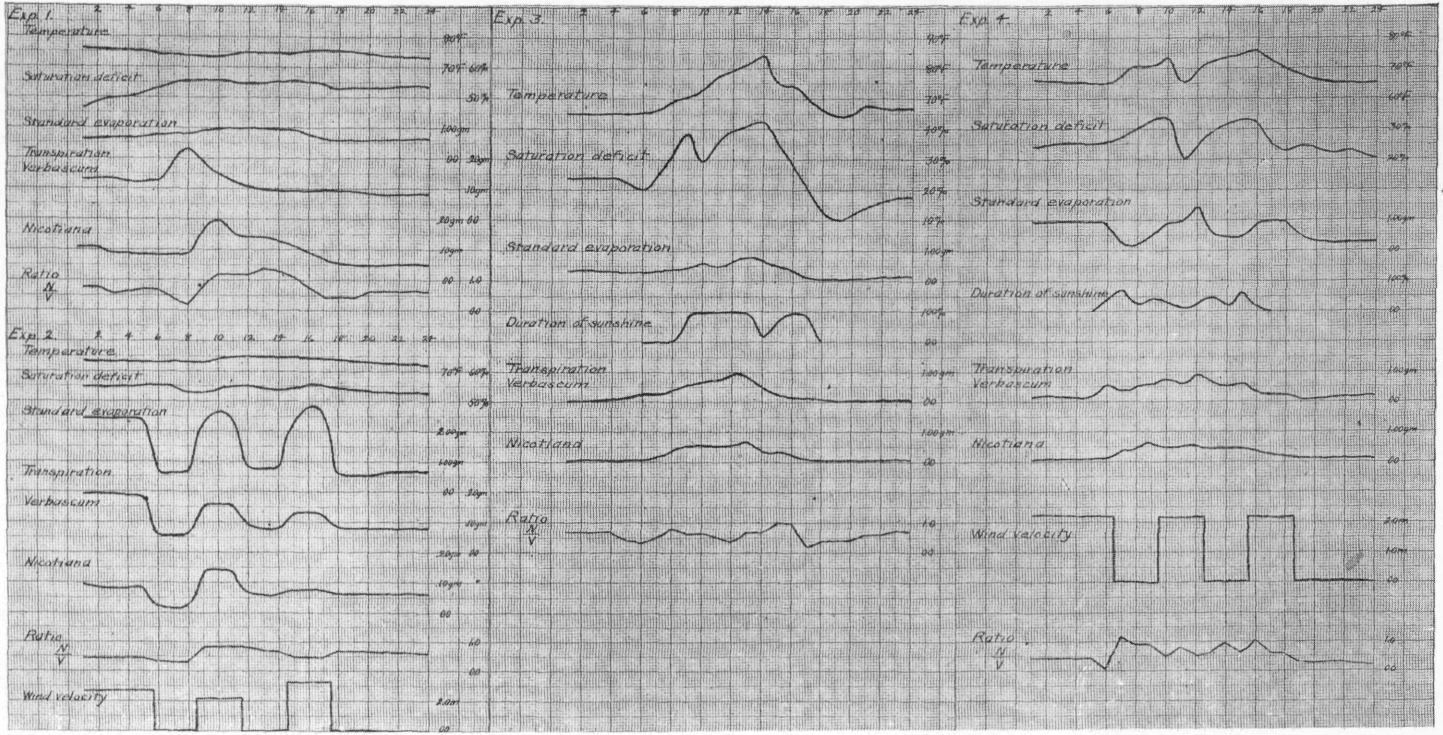

Fig. 3. Series I. Experiments 1, 2, 3 and 4.

leaves showed no rupture of living cells. The hairs were removed from the half grown leaf with curved forceps, and the leaves were allowed to grow to full size before the experiments were performed.

SERIES I. There are four experiments in this series, each one of which has one or more of the environmental conditions different from the other. The table below gives the condition under which each experiment was performed. The same two plants were used in each one of the experiments.

SERIES I.

Experiment 1. Darkroom, still air.
2. Darkroom, wind.
3. Greenhouse, still air.
4. Greenhouse, wind.

The purpose of changing the conditions to which the plants were exposed was to see what comparative effect the conditions have on the resistance of the leaves to water loss. For example, wind increases transpiration, and as both plants are exposed to the same wind velocity, in order to determine their comparative resistance to water loss in wind, we compared their ratios in still air to their ratios in wind. If the ratios are the same each plant has resisted the wind to the same degree, but if they are different one of the plants has offered more or less resistance to the wind than the other. By comparing ratios, the resistance of the leaves to water loss under different conditions can be determined. The ratios used in the first four experiments are the $\frac{\text{transpiration of tobacco}}{\text{transpiration of mullein}}$ for the same time and under the same conditions, which for convenience will be designated as $\frac{\text{tobacco}}{\text{mullein}}$. (In the tables and curves simply as $\frac{N}{V}$).

Experiment 1. The hourly results of experiment 1, which was performed in the darkroom in still air, are tabulated on page 76, and expressed as curves on page 64. The temperature, saturation, deficit, and evaporation are almost constant under the conditions in the darkroom, while the transpiration rates show a rhythm in the curve about the middle

Fig. 4. Series II-a. Experiments 5, 6 and 7.

of the forenoon. The hourly ratios of the water loss from the two plants vary from 0.60 to 1.40 and the ratio for the total daily water loss is 0.81.

Experiment 2. This experiment was performed under conditions similar to experiment 1, except that an electric fan was used to produce wind, at three hour intervals. The tabulated results (page 76) and curves (page 64) show that under these conditions the temperature and saturation deficit are constant throughout the day while the results for water loss are determined by the wind velocity. The evaporation is proportional to the wind velocity, but the transpiration does not show these results, although the water loss of each plant is increased by the wind. In tobacco the highest rate of water loss is during the time when the wind velocity is least and the highest wind velocity produces the smallest increase in the rates of both plants. These irregularities are due to the fact that there is a rhythm in the curve at the time of the second interval as shown in experiment 1. The hourly ratios show less variation under the conditions of this experiment than in experiment 1, and the total daily ratio of water loss is considerably decreased; 0.59.

Experiment 3. The tabulated hourly rates of this experiment, which was performed in the Greenhouse in still air, are given on page 77 and a set of curves to correspond to this table on page 64. The variations in temperature and saturation deficit in this experiment are due to sunlight which increases them. The rates of evaporation correspond to the increased temperature and saturation deficit. There is a greater variation between the maximum and minimum rates of transpiration than in either of the two preceding experiments, due to the sunlight. This experiment is taken as a standard for comparison with the other experiments because the conditions are those to which plants are usually exposed. The total daily ratio for this experiment is 0.69.

Experiment 4. This experiment was similar to experiment 3, except an electric fan was used to produce wind, at three hour intervals as in experiment 2. The results are given on pages 77 and 64. The variations in temperature and saturation deficit occur according to the periods of day and night. The evaporation is proportional to the wind velocity, taking into consideration the changes in temperature and saturation

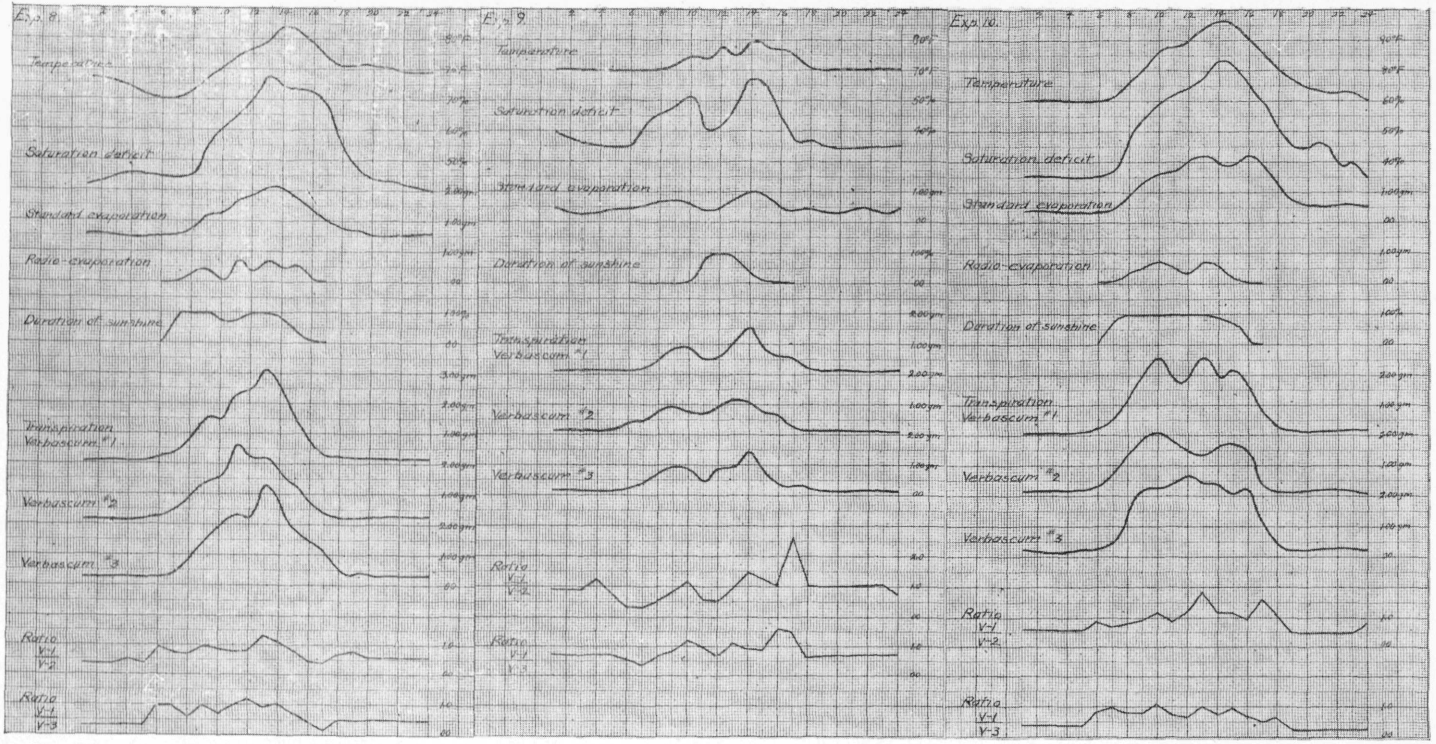

Fig. 5. Series II-b. Experiments 8, 9 and 10.

deficit. The variations in the transpiration rates are not proportional to the wind velocity or to the evaporation although there is some increase due to the wind. The total daily ratio for this experiment is 0.65.

In order to bring the results of the first four experiments together in a more compact form, a table of totals and ratios was made. This table (Table III, page 84) gives total day, night and daily rates of transpiration and evaporation for each experiment, and in experiment 2 and 4 the total rate for the still air and the wind intervals. The mean temperature and saturation deficit for each corresponding period are also shown.

SERIES II. There are twelve experiments in this series which is divided into four sub-series of three experiments each. The same plants were used throughout the entire series. The transpiration rates of three mullein plants were obtained by the same method as in series I. In series II-a the normal plants were used, but in the rest of the experiments the hairs were removed from the upper leaf surfaces of one plant and from the lower leaf surface of another, while the third plant was left normal throughout the series. Each sub-series has some condition changed or modified, as in the different experiments of series I, which are given in the accompanying table.

Series II.

Series II-a. Normal plants, greenhouse, still air.
Series II-b. Hairs removed, greenhouse, still air.
Series II-c. Hairs removed, greenhouse, wind.
Series II-d. Hairs removed, darkroom, still air.

SERIES II-a. Experiments 5, 6 and 7, which are the results of this sub-series are given on pages 78-79, in a tabulated form, and on page 66 in the form of curves. These results show the daily march of transpiration and give a record of the common factors influencing water loss from plants. These curves represent the ordinary rates of water loss from plants of this type. Table IV, on page 84, which gives totals and ratios for this series, shows that even from plants of the same species under the same conditions, the rate of water loss is not necessarily the same. This is shown by the ratios given in this table as well as by the total rate of water

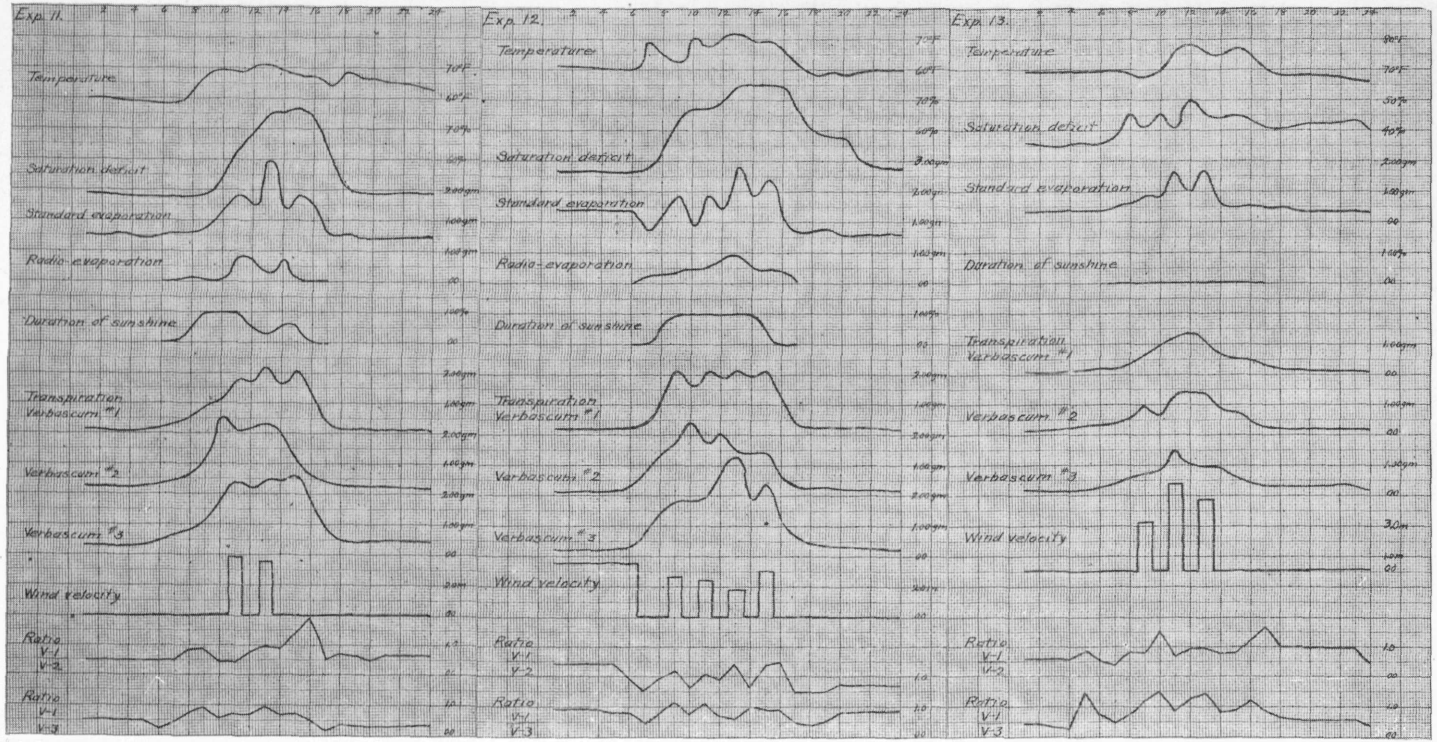

Fig. 6. Series II-c. Experiments 11, 12 and 13.

loss. The ratios which are used in this series (series II) are the $\frac{\text{transpiration of mullein}^1}{\text{transpiration of mullein}^2}$ for the same conditions and the $\frac{\text{transpiration of mullein}^1}{\text{transpiration of mullein}^3}$ for the same conditions. (Designated in the tables and curves as $\frac{\text{V-1}}{\text{V-2}}$ and $\frac{\text{V-1}}{\text{V-3}}$).

SERIES II-b. The results of this sub-series, experiments 8, 9 and 10, are given on pages 79–80 and 68. In this series mullein has the normal thick coat of hairs on its leaf surfaces, mullein^2 has the hairs removed from the upper surfaces of all the leaves, and mullein^3 has the hairs removed from the lower surfaces of all the leaves. The conditions under which the experiments of this series are run are similar to those of series II-a, or in still air in the greenhouse. The results show the daily march of transpiration, and the environmental factors. The table of totals and ratios (Table V, page 85,) shows that the removal of the hairs has not changed the ratios for the daily rates. $\frac{M^{1+h}}{M^{2+h}}=0.98$, and $\frac{M^{1+h}}{M^{3+h}}=0.82$ in series II-a, while in series II-b these are 0.99 and 0.83.

SERIES II-c. This sub-series of experiments was performed under the same conditions as series II-b, except that an electric fan was used to produce wind at hour intervals. Experiments 11, 12 and 13, on pages 81–82 and 70, are the results of this sub-series. The wind produces considerable increases in the evaporation rates, but there is no marked differences in the transpiration rates of the three plants. In Table VI, which gives the totals and ratios for this sub-series, the totals for still air and wind intervals are shown, in addition to the other totals. The total ratios for this sub-series are $\frac{M^{1+h}}{M^{2-h}}=0.91$ and $\frac{M^{1+h}}{M^{3-h}}=0.78$.

SERIES II-d. The same plants that were used in the first three sub-series of this series were placed in the darkroom and a record of the water loss obtained for three days. These results are given as experiments 14, 15 and 16, on pages 82–83 and a set of curves made for these experiments on page 72. Table VII gives the totals and ratios for this sub-series: $\frac{M^{1+h}}{M^{2-h}}=0.56$ and $\frac{M^{1+h}}{M^{3-h}}=0.65$.

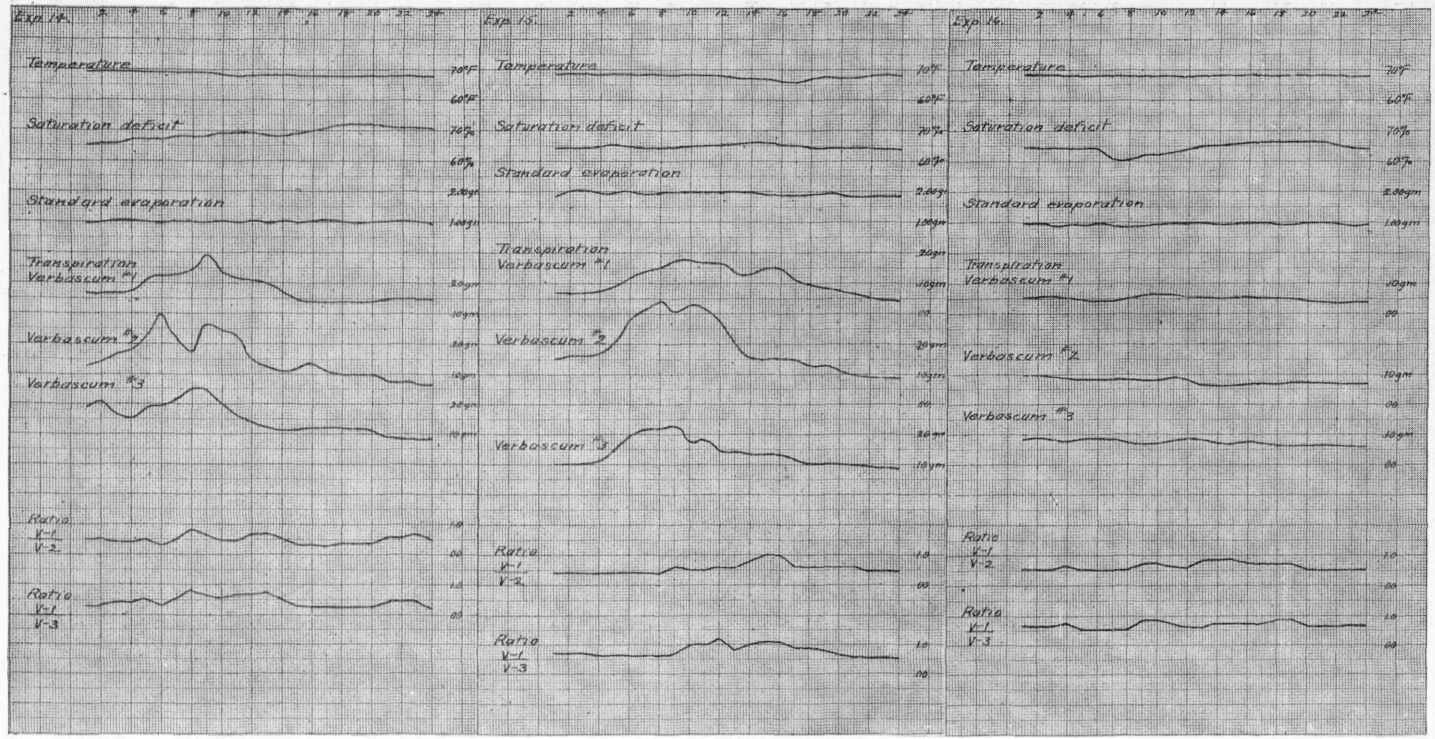

Fig. 7. Series II-d. Experiments 14, 15 and 16.

Conclusions.

The conclusions from the experiments in this paper are drawn from a comparison of the ratios given in the tables. The ratio $\frac{\text{tobacco}}{\text{mullein}}$ from experiment 3 is taken as a standard for comparison in series I, and the ratio $\frac{\text{mullein}^1}{\text{mullein}^2}$ and $\frac{\text{mullein}^1}{\text{mullein}^3}$ from experiments 5, 6 and 7 or sub-series–a as standard for comparison in series II. These represent the ratios of water loss in still air, and sunlight, or those conditions to which plants are more commonly subjected. For comparison, we assume that the numerator of the ratios does not change except in direct proportion to the environmental factors. For example, wind increases both the numerator and the denominator of the ratios or the transpiration of the two plants, but perhaps not to the same degree as when their rates are compared in still air. Under this assumption, any change in the ratios is due to an increase or a decrease in the transpiration rates of the plants used as the denominators as compared to the other plants. In the first series of experiments tobacco was used as a suitable plant with which to compare mullein, because of the very similar leaf structures of the two plants, except the absence of a hairy leaf covering on tobacco. In the second series normal mullein plants were compared with plants having the hairy covering of the leaves removed. These comparisons are made of daily results rather than hourly figures, because there is a great fluctuation in the hourly rates in some experiments and daily figures represent the average of these results.

By comparing the ratio $\frac{\text{tobacco}}{\text{mullein}}$ $(=0.69)$ in still air and light with the ratio $(=0.81)$ in still air and darkness it shows that there was a greater resistance of the mullein leaves to water loss in darkness than in light. A comparison of the ratio $(=0.69)$ in still air and light with the ratio $(=0.65)$ in wind and light shows that there was a very slight decrease in the resistance of the mullein leaves to water loss in wind than in still air. The comparison of the ratio $(=0.85)$ from the still air intervals of experiment 4 and the ratio $(=0.57)$ from the wind intervals of the same experiment and the ratio $(=0.68)$ from the still air intervals of experiment 2 and the ratio $(=0.56)$ from

the wind intervals show that the mullein leaves offer less resistance to water loss in wind than in still air. A summary of these comparisons gives the following conclusions:

1. Mullein leaves offer a greater resistance to water loss in darkness than in light when compared with tobacco leaves.
2. Mullein leaves offer less resistance to water loss in wind than in still air when compared with tobacco leaves.
3. Mullein leaves respond as much or more to changes in the environment than tobacco leaves.

The ratios of sub-series-a in series II are taken as standard for comparing the other ratios of the series, because all plants are normal. The total ratios for the three experiments are compared in each sub-series. The two standard ratios are ($=0.98$) and) $=0.82$) their difference being due to the differences in transpiration rates of equal leaf areas of several plants of the same species even under identical conditions. These ratios, when the hairs are removed from the plants, become ($=0.99$) and ($=0.83$) which shows that the removal of the hair does not alter the resistance of the leaves to water loss. When the ratios of the same plants in wind and light with the hair removed are found ($=0.91$) and ($=0.78$) we see that the removal of the hairs has slightly decreased the resistance of the leaves to water loss in wind when compared with still air. This difference is due to the fact that a larger cuticular surface is exposed to the evaporating powers of the air when the hairs are removed, and that wind increases water loss from this exposed surface more than the usual rate in still air. This difference, however, is very slight as compared with the internal surface of the leaf. When the plants are placed in a darkroom and the ratios of the results obtained there are compared ($=0.56$) and ($=0.65$) there is a great difference noticed. The effect of removing the hairs from the leaves is to greatly increase the resistance in darkness as compared with plants having hairs in light. This increase, however, is caused by the increased transpiration, which in darkness is cuticular because the stomata are closed, and is much larger because a greater surface is exposed to the evaporating power of the air. Series II, therefore, warrants the following conclusions:

4. The removal of the hairs from the mullein leaves does not alter the resistance of the leaves to water loss in still air and light.

5. The removal of the hairs slightly decreased the resistance of the leaves to water loss in wind and light as compared to still air and light, because the cuticular surface is more exposed to the air.

6. The removal of the hairs greatly decreased the resistance of the leaves to water loss in still air and darkness as compared with still air and light. This is due to the greater exposure of the cuticular surface. In darkness the stomata are closed and transpiration is almost entirely cuticular.

7. Hairs as a protective covering against ordinary intensities of wind and light on mullein leaves may be disregarded. The water loss from the leaves is mostly from the internal (mesophyll) surface of the leaves. The internal water loss is from twenty to forty times greater than the external or cuticular water loss (on the basis of increased transpiration due to stomatal openings minus increased evaporation caused by increased environmental factors). The removal of the hairs increases total transpiration only to the extent that the cuticular surface is more exposed and has apparently no effect on stomatal transpiration.

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EXPERIMENT 1—DARKROOM.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Transpiration, Verbascum. Grams per Sq. Dm. per hour.	Transpiration, Nicotiana. Grams per Sq. Dm. per hour.	Ratio $\frac{N}{V}$
1	75	46	.66	.13	.11	.8
2	75	48	.66	.13	.11	.8
3	75	49	.66	.13	.09	.6
4	75	50	.70	.12	.09	.7
5	75	52	.76	.12	.09	.7
6	74	53	.78	.12	.09	.7
7	74	55	.82	.20	.09	.4
8	74	56	.91	.24	.09	.3
9	73	56	.95	.19	.19	1.0
10	73	56	.99	.16	.20	1.2
11	74	55	.95	.12	.15	1.2
12	74	55	.95	.11	.14	1.2
13	74	55	.95	.10	.14	1.4
14	74	55	.90	.09	.12	1.3
15	74	55	.90	.09	.10	1.1
16	75	55	.80	.09	.08	.8
17	75	54	.63	.09	.05	.5
18	75	53	.63	.09	.05	.5
19	74	53	.63	.09	.05	.5
20	74	53	.63	.08	.05	.6
21	73	53	.63	.08	.05	.6
22	73	54	.63	.08	.05	.6
23	73	54	.63	.08	.05	.6
24	73	54	.63	.08	.05	.6

EXPERIMENT 2—DARKROOM.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Transpiration, Verbascum. Grams per Sq. Dm. per hour.	Transpiration, Nicotiana. Grams per Sq. Dm. per hour.	Wind Velocity. Miles per hour.	Ratio $\frac{N}{V}$
1	73	55	2.46	.20	.09	2.7	.4
2	73	55	2.46	.19	.08	2.7	.4
3	73	55	2.46	.19	.08	2.7	.4
4	73	55	2.42	.19	.08	2.7	.4
5	73	55	2.46	.19	.08	2.7	.4
6	73	55	.61	.06	.02	.....	.3
7	73	54	.66	.06	.02	.....	.3
8	73	53	.61	.06	.02	.....	.3
9	73	53	2.36	.16	.14	2.2	.8
10	74	54	2.70	.16	.14	2.2	.8
11	74	55	2.46	.16	.14	2.2	.8
12	74	55	.80	.08	.07	.....	.8
13	74	54	.80	.08	.06	.....	.7
14	74	54	.80	.08	.06	.....	.7
15	74	54	2.36	.13	.07	3.3	.5
16	74	55	2.90	.13	.07	3.3	.5
17	74	55	2.70	.13	.07	3.3	.5
18	73	54	.56	.08	.06	.....	.7
19	73	53	.56	.08	.06	.....	.7
20	73	53	.56	.08	.06	.....	.7
21	73	53	.61	.08	.06	.....	.7
22	72	52	.66	.08	.06	.....	.7
23	72	52	.66	.08	.06	.....	.7
24	72	52	.66	.08	.06	.....	.7

EXPERIMENT 3—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum. Grams per Sq. Dm. per hour.	Transpiration, Nicotiana. Grams per Sq. Dm. per hour.	Ratio $\frac{N}{V}$
1	66	24	.32	.....	.09	.07	.7
2	66	24	.32	.....	.09	.07	.7
3	66	24	.32	.....	.10	.07	.7
4	66	24	.32	.....	.12	.09	.7
5	65	23	.28	.....	.14	.10	.5
6	66	20	.23	00	.28	.12	.4
7	67	25	.32	00	.28	.17	.5
8	70	32	.42	00	.45	.40	.8
9	71	39	.47	90	.64	.52	.7
10	74	30	.66	100	.72	.53	.7
11	78	37	.47	100	.79	.53	.6
12	80	40	.70	100	1.00	.55	.5
13	82	41	.89	100	.94	.70	.7
14	85	43	.70	20	.50	.35	.7
15	75	36	.52	70	.32	.32	1.0
16	75	30	.38	100	.24	.25	1.0
17	70	20	.09	100	.21	.06	.2
18	67	14	.09	.....	.15	.06	.4
19	64	11	.09	.....	.10	.05	.5
20	65	13	.13	.....	.10	.05	.5
21	68	15	.13	.....	.10	.06	.6
22	67	17	.13	.....	.10	.06	.6
23	67	18	.17	.....	.10	.07	.7
24	67	18	.17	.....	.10	.07	.7

EXPERIMENT 4—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum. Grams per Sq. Dm. per hour.	Transpiration, Nicotiana. Grams per Sq. Dm. per hour.	Wind Velocity. Miles per hour.	Ratio $\frac{N}{V}$
1	66	24	.95	.....	.19	.09	2.2	.4
2	66	25	.95	.....	.16	.07	2.2	.4
3	66	25	.95	.....	.15	.07	2.2	.4
4	65	25	.95	.....	.15	.07	2.2	.4
5	65	25	.95	.....	.14	.07	2.2	.4
6	65	26	.95	40	.53	.07	2.2	.1
7	69	28	.23	70	.24	.30	.....	1.2
8	71	31	.23	20	.50	.45	.....	.9
9	71	33	.47	40	.64	.61	.....	.9
10	74	40	.95	30	.77	.45	2.2	.5
11	65	20	.95	10	.52	.45	2.2	.8
12	70	25	1.42	20	.85	.50	2.2	.5
13	72	30	.47	50	.64	.45	.....	.7
14	74	32	.47	10	.51	.47	.....	.9
15	75	33	.47	60	.60	.38	.....	.6
16	76	33	.95	00	.28	.31	2.2	1.1
17	72	25	.95	00	.21	.13	2.2	.6
18	70	23	.95	.....	.21	.13	2.2	.6
19	68	25	.47	.....	.08	.03	.....	.3
20	66	24	.23	.....	.12	.04	.....	.3
21	65	23	.23	.....	.13	.04	.....	.3
22	65	23	.23	.....	.14	.04	.....	.2
23	65	22	.23	.....	.14	.04	.....	.2
24	65	20	.23	.....	.14	.04	.....	.2

EXPERIMENT 5—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	66	38	.46	.....	.....	.05	.09	.07	.5	.7
2	65	38	.44	.....	.....	.05	.09	.07	.5	.7
3	64	38	.39	.....	.....	.05	.09	.07	.5	.7
4	63	39	.38	.....	.....	.05	.09	.07	.5	.7
5	62	39	.48	.....	.....	.05	.09	.07	.5	.7
6	61	39	.38	.10	00	.20	.09	.17	2.2	1.1
7	61	38	.32	.13	00	.50	.28	.31	1.7	1.6
8	65	36	.39	.16	10	.57	.35	.37	1.6	1.5
9	69	40	.67	.15	60	.85	.42	.60	2.0	1.4
10	75	55	.91	.37	100	1.06	1.11	1.07	.9	.9
11	83	65	1.55	.45	50	1.71	1.42	1.74	1.2	.9
12	85	75	1.93	.17	90	2.14	1.80	1.81	1.1	1.1
13	87	78	1.93	.49	50	2.14	1.90	2.26	1.1	.9
14	89	78	1.93	.72	100	2.29	1.80	2.26	1.2	1.0
15	91	79	2.42	.23	100	1.92	2.00	1.92	.9	1.0
16	88	79	2.16	.00	50	1.60	1.23	1.22	1.3	1.3
17	83	75	1.02	.00	00	.54	.78	.56	.7	.9
18	78	60	.50	.....	.....	.08	.10	.23	.8	.3
19	76	45	.40	.....	.....	.08	.10	.16	.8	.5
20	73	44	.42	.....	.....	.08	.10	.13	.8	.6
21	71	43	.42	.....	.....	.08	.10	.13	.8	.6
22	69	42	.40	.....	.....	.08	.10	.13	.8	.6
23	67	42	.42	.....	.....	.08	.10	.13	.8	.6
24	66	42	.44	.....	.....	.08	.10	.13	.8	.6

NOTE: All plants normal.

EXPERIMENT 6—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	65	41	.45	.....	.....	.08	.09	.10	.8	.8
2	64	41	.45	.....	.....	.08	.09	.10	.8	.8
3	63	41	.45	.....	.....	.08	.09	.10	.8	.8
4	62	41	.35	.....	.....	.08	.09	.10	.8	.8
5	61	41	.43	.....	.....	.08	.09	.22	.8	.3
6	60	40	.43	.00	00	.13	.16	.24	.8	.5
7	60	40	.43	.04	70	.31	.33	.28	.9	1.1
8	62	40	.56	.39	100	1.13	.53	.91	2.1	1.2
9	70	45	1.23	.41	100	1.41	1.33	2.18	1.0	.6
10	80	60	2.10	.70	100	2.10	2.48	3.04	.8	.6
11	85	75	1.77	.81	100	2.50	2.68	3.04	.9	.8
12	90	77	2.73	.49	100	3.38	3.06	3.92	1.1	.8
13	93	81	2.73	.59	100	3.10	2.80	3.92	1.1	.7
14	95	82	2.90	.24	100	1.83	2.42	3.26	.7	.5
15	93	81	2.42	.48	100	1.83	1.65	3.26	1.1	.5
16	90	79	1.93	.00	10	.52	1.60	2.38	.3	.2
17	85	75	1.04	.00	00	.10	.68	.87	.1	.1
18	78	60	.44	.....	.....	.09	.13	.28	.6	.3
19	74	45	.38	.....	.....	.09	.13	.13	.6	.6
20	72	38	.38	.....	.....	.09	.13	.13	.6	.6
21	72	37	.38	.....	.....	.09	.13	.13	.6	.6
22	71	37	.38	.....	.....	.09	.13	.13	.6	.6
23	70	37	.38	.....	.....	.09	.13	.13	.6	.6
24	70	37	.38	.....	.....	.09	.13	.13	.6	.6

NOTE: All plants normal.

EXPERIMENT 7—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	70	37	.41	.....	.....	.09	.12	.13	.7	.6
2	69	37	.35	.....	.....	.09	.12	.13	.7	.6
3	69	35	.35	.....	.....	.09	.12	.13	.7	.6
4	69	35	.37	.....	.....	.09	.12	.13	.7	.6
5	69	35	.41	.....	.....	.09	.12	.13	.7	.6
6	68	35	.35	.00	00	.18	.16	.13	1.1	1.3
7	69	34	.35	.00	00	.18	.16	.25	1.1	.7
8	70	34	.35	.00	00	.31	.30	.31	1.0	1.0
9	71	36	.50	.12	00	.43	.50	.51	.8	.8
10	72	45	.91	.02	00	.47	.97	1.00	.4	.4
11	72	55	.97	.14	20	1.57	1.15	1.31	1.3	1.2
12	83	60	1.20	.58	90	1.96	2.31	1.75	.9	1.1
13	87	75	2.25	.40	100	2.15	1.94	2.62	1.0	.8
14	87	81	2.34	.56	100	2.55	2.38	2.85	1.0	.8
15	87	83	2.04	.86	60	2.74	3.03	2.85	.9	.9
16	87	82	1.95	.00	40	1.70	2.02	1.97	.8	.8
17	83	75	1.20	.00	00	.82	1.01	.98	.8	.8
18	77	66	.70	.....	.....	.22	.12	.19	1.7	1.1
19	73	45	.55	.....	.....	.08	.12	.13	.6	.6
20	71	38	.44	.....	.....	.08	.12	.13	.6	.6
21	70	36	.35	.....	.....	.08	.12	.13	.6	.6
22	68	35	.35	.....	.....	.08	.12	.13	.6	.6
23	66	34	.35	.....	.....	.08	.12	.13	.6	.6
24	65	34	.35	.....	.....	.08	.12	.13	.6	.6

NOTE: All plants normal.

EXPERIMENT 8—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	67	42	.52	.....	.....	.08	.19	.23	.4	.3
2	66	43	.57	.....	.....	.08	.21	.24	.3	.3
3	65	45	.46	.....	.....	.09	.18	.24	.4	.3
4	64	46	.45	.....	.....	.09	.18	.23	.5	.3
5	62	45	.44	.....	.....	.09	.19	.23	.4	.3
6	61	45	.44	.04	00	.25	.24	.25	1.0	1.0
7	60	45	.52	.03	100	.36	.48	.38	.7	.9
8	63	45	.70	.37	100	.70	.96	1.05	.7	.6
9	68	55	1.25	.37	100	1.53	1.42	1.40	1.0	1.0
10	70	60	1.25	01	70	1.49	1.51	2.08	.9	.7
11	75	65	1.67	72	80	2.24	2.65	2.33	.8	.9
12	77	70	1.84	.39	100	2.45	2.65	2.20	.9	1.1
13	79	78	2.08	.71	100	3.11	2.27	3.30	1.3	.9
14	85	75	2.08	.56	80	2.56	2.27	2.58	1.1	1.0
15	82	74	1.63	.53	30	1.44	1.70	1.84	.8	.7
16	80	73	1.36	.00	00	.64	1.32	1.47	.4	.4
17	73	68	.85	.00	00	.25	.63	.90	.3	.2
18	71	55	.72	.....	.....	.21	.29	.36	.7	.5
19	72	46	.62	.....	.....	.19	.22	.32	.8	.5
20	71	44	.49	.....	.....	.13	.21	.24	.6	.5
21	70	43	.52	.....	.....	.13	.21	.25	.6	.5
22	69	42	.52	.....	.....	.13	.21	.25	.6	.5
23	69	41	.52	.....	.....	.13	.21	.25	.6	.5
24	69	40	.52	.....	.....	.13	.21	.25	.6	.5

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 9—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Duration of Sunshine, Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	70	40	.44	.....	.13	.14	.18	.9	.7
2	70	38	.35	.....	.13	.14	.18	.9	.7
3	70	37	.30	.....	.13	.14	.18	.9	.7
4	70	36	.33	.....	.13	.10	.18	1.3	.7
5	70	35	.41	.....	.13	.15	.18	.8	.7
6	70	35	.44	00	.14	.32	.21	.4	.6
7	70	43	.67	00	.16	.47	.44	.3	.3
8	70	46	.70	00	.52	.87	.82	.5	.6
9	72	49	.73	00	.81	.97	.98	.8	.8
10	75	52	.63	00	.94	.77	.82	1.2	1.1
11	73	40	.41	90	.47	.77	.45	.6	1.0
12	78	42	.55	90	.63	.97	.86	.6	.7
13	74	48	.80	70	1.10	1.17	.98	.9	1.1
14	80	58	1.05	40	1.57	1.02	1.48	1.5	1.0
15	78	55	.87	00	.88	.73	.93	1.2	.9
16	77	45	.41	00	.64	.58	.36	1.1	1.7
17	75	37	.48	00	.54	.19	.34	2.8	1.5
18	70	37	.41	.....	.14	.14	.22	1.0	.6
19	70	35	.33	.....	.14	.14	.19	1.0	.7
20	70	35	.30	.....	.14	.14	.19	1.0	.7
21	70	35	.44	.....	.14	.14	.19	1.0	.7
22	70	35	.45	.....	.14	.14	.19	1.0	.7
23	70	35	.29	.....	.14	.14	.19	1.0	.7
24	70	43	.44	.....	.13	.14	.18	.9	.7

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 10—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine, Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	70	35	.32	.....	.....	.08	.13	.21	.6	.3
2	70	35	.33	.....	.....	.08	.13	.17	.6	.4
3	70	35	.35	.....	.....	.08	.13	.17	.6	.4
4	70	35	.30	.....	.....	.08	.13	.19	.6	.4
5	70	35	.33	.....	.....	.12	.18	.24	.6	.4
6	70	36	.33	.07	10	.22	.26	.27	.8	.8
7	72	37	.44	.13	100	.47	.63	.46	.7	1.0
8	77	48	.92	.42	100	1.09	1.34	1.35	.8	.8
9	80	55	1.35	.58	100	1.84	1.87	2.26	.9	.8
10	87	60	1.68	.73	100	2.64	2.14	2.26	1.2	1.1
11	88	62	1.68	.55	100	1.70	1.87	2.41	.9	.7
12	90	65	2.10	.32	100	2.00	1.60	2.71	1.2	.7
13	95	68	2.25	.79	100	2.64	1.34	2.41	1.9	1.0
14	97	74	1.93	.68	90	2.00	1.60	2.41	1.2	.8
15	95	72	2.22	.17	80	2.28	1.74	2.10	1.3	1.0
16	90	65	1.93	.12	00	1.70	1.51	2.30	1.0	.7
17	85	60	1.18	.00	00	.64	.38	1.13	1.6	.5
18	80	50	.66	.....	.....	.22	.20	.31	1.1	.7
19	76	44	.54	.....	.....	.11	.20	.30	.5	.3
20	74	45	.54	.....	.....	.11	.20	.30	.5	.3
21	73	47	.54	.....	.....	.11	.20	.30	.5	.3
22	73	39	.54	.....	.....	.11	.20	.30	.5	.3
23	73	40	.54	.....	.....	.11	.20	.30	.5	.3
24	70	35	.54	.....	.....	.09	.11	.21	.8	.4

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 11—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Wind Velocity. Miles per hour.	Ratio V-1/V-2	Ratio V-1/V-3
1	60	48	.55	.....	.....	.12	.25	.24	.....	.4	.5
2	59	48	.59	.....	.....	.12	.25	.24	.....	.4	.5
3	59	48	.66	.....	.....	.12	.25	.24	.....	.4	.5
4	59	48	.55	.....	.....	.12	.25	.24	.....	.4	.5
5	58	48	.54	.....	.....	.12	.25	.30	.....	.4	.4
6	58	48	.61	.00	00	.12	.30	.44	.....	.4	.2
7	58	48	.55	.07	00	.27	.49	.65	.....	.5	.4
8	65	48	.52	.17	80	.62	.71	.78	.....	.8	.7
9	68	48	.90	.00	100	.96	1.13	1.10	.....	.8	.8
10	70	55	1.54	.00	100	1.11	2.58	1.75	.....	.4	.6
11	68	64	1.93	.97	100	1.88	2.18	2.40	4.0	.5	.7
12	72	70	1.42	.75	40	1.67	2.18	2.13	.....	.7	.7
13	72	75	3.14	.23	30	2.30	2.38	2.40	3.5	.9	.9
14	69	76	1.42	.75	60	1.67	1.99	2.40	.....	.8	.6
15	68	77	1.93	.00	60	2.10	1.18	2.66	.....	1.7	.7
16	68	75	1.56	.00	00	1.25	.59	1.88	.....	2.1	.6
17	63	63	.66	.00	00	.16	.37	.91	.....	.4	.1
18	69	50	.64	.....	.....	.16	.25	.45	.....	.6	.3
19	68	49	.55	.....	.....	.16	.25	.45	.....	.6	.3
20	67	49	.55	.....	.....	.16	.25	.45	.....	.5	.3
21	66	49	.55	.....	.....	.16	.25	.45	.....	.6	.3
22	64	48	.55	.....	.....	.16	.25	.45	.....	.6	.3
23	63	48	.55	.....	.....	.16	.25	.45	.....	.6	.3
24	63	48	.55	.....	.....	.16	.25	.45	.....	.6	.3

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 12—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Radio-evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Wind Velocity. Miles per hour.	Ratio V-1/V-2	Ratio V-1/V-3
1	62	47	1.43	.....	.....	.20	.15	.22	3.5	1.3	.9
2	61	47	1.43	.....	.....	.20	.15	.22	3.5	1.3	.9
3	61	47	1.43	.....	.....	.20	.15	.22	3.5	1.3	.9
4	60	47	1.43	.....	.....	.20	.15	.22	3.5	1.3	.9
5	60	47	1.43	.....	.....	.20	.15	.23	3.5	1.3	.8
6	60	47	1.43	.00	00	.20	.21	.23	3.5	.9	.8
7	70	47	.72	.25	00	.36	.70	.81	.....	.5	.4
8	65	55	1.19	.26	80	1.22	1.33	1.55	.....	.9	.7
9	62	65	1.93	.37	100	2.18	1.68	1.88	2.6	1.2	1.1
10	71	67	.96	.48	100	1.58	2.43	1.88	.....	.6	.8
11	68	67	1.93	.48	100	2.18	1.68	1.88	2.2	1.2	1.1
12	72	70	1.42	.96	100	1.98	2.04	2.82	.....	.9	.7
13	72	75	2.90	.96	100	2.18	1.49	3.30	1.9	1.4	.6
14	70	75	1.93	.48	100	1.98	2.99	1.88	.....	.6	1.0
15	70	75	2.41	.45	20	2.18	1.49	2.36	3.0	1.4	.9
16	66	75	1.10	.34	00	1.03	.66	1.09	.....	1.5	.9
17	60	65	.77	.17	00	.23	.39	.45	.....	.5	.5
18	58	61	.77	.....	.....	.22	.28	.46	.....	.5	.4
19	60	58	.76	.....	.....	.18	.27	.31	.....	.6	.5
20	58	58	.58	.....	.....	.18	.23	.22	.....	.7	.8
21	60	50	.58	.....	.....	.18	.23	.22	.....	.7	.8
22	60	48	.58	.....	.....	.18	.23	.22	.....	.7	.8
23	60	48	.58	.....	.....	.18	.23	.22	.....	.7	.8
24	60	47	.58	.....	.....	.18	.23	.22	.....	.7	.8

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 13—GREENHOUSE.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Duration of Sunshine. Per cent per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Wind Velocity. Miles per hour.	Ratio V-1/V-2	Ratio V-1/V-3
1	69	36	.30	.....	.06	.12	.13	.....	.5	.4
2	69	35	.30	.....	.06	.12	.13	.....	.5	.4
3	69	34	.32	.....	.06	.12	.16	.....	.5	.3
4	69	35	.32	.....	.06	.23	.16	.....	.5	.3
5	69	35	.32	.....	.17	.20	.11	.....	.8	1.5
6	69	35	.35	00	.17	.29	.20	.....	.5	.8
7	69	38	.50	00	.18	.40	.36	.....	.4	.5
8	68	45	.53	00	.41	.52	.60	.....	.7	.6
9	67	40	.90	00	.77	1.00	.69	3.2	.7	1.1
10	69	45	.71	00	1.00	.53	.77	.....	1.8	1.4
11	77	40	1.69	00	1.16	1.38	1.42	5.6	.6	.8
12	78	50	.96	00	1.33	1.38	1.03	.....	.9	1.2
13	76	45	1.69	00	1.16	1.22	.88	4.7	.9	1.3
14	75	44	.48	00	.66	.81	.86	.....	.8	.7
15	77	45	.48	00	.50	.71	.56	.....	.7	.8
16	74	43	.55	00	.46	.38	.38	.....	1.2	1.2
17	70	40	.41	00	.26	.15	.30	.....	1.7	.8
18	68	40	.48	.....	.16	.15	.26	.....	1.0	.6
19	68	41	.30	.....	.14	.15	.26	.....	.9	.5
20	68	42	.30	.....	.14	.15	.26	.....	.9	.5
21	67	42	.30	.....	.14	.15	.26	.....	.9	.5
22	67	42	.30	.....	.14	.15	.26	.....	.9	.5
23	66	43	.30	.....	.14	.15	.26	.....	.9	.5
24	70	40	.30	.....	.06	.12	.13	.....	.5	.4

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 14—DARKROOM.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1/V-2	Ratio V-1/V-3
1	69	65	.99	.07	.13	.19	.5	.3
2	69	66	.97	.07	.14	.21	.5	.3
3	69	66	1.01	.07	.16	.17	.4	.4
4	69	67	1.00	.07	.16	.15	.4	.4
5	69	67	.99	.12	.23	.19	.5	.5
6	69	67	.97	.12	.31	.19	.3	.3
7	69	68	.97	.13	.21	.23	.5	.6
8	69	68	.97	.14	.17	.26	.8	.8
9	69	68	.97	.19	.27	.25	.7	.7
10	68	69	1.02	.13	.25	.20	.5	.6
11	68	69	.99	.12	.23	.16	.5	.7
12	68	69	1.01	.11	.15	.14	.7	.7
13	68	68	.96	.10	.13	.12	.7	.8
14	68	68	1.09	.07	.11	.12	.6	.5
15	68	69	.97	.04	.12	.12	.3	.3
16	68	70	1.08	.04	.13	.12	.3	.3
17	68	71	1.07	.04	.11	.12	.3	.3
18	68	72	1.06	.04	.10	.12	.4	.3
19	68	72	1.00	.04	.10	.12	.4	.3
20	68	72	1.01	.04	.10	.12	.4	.3
21	68	71	1.05	.05	.08	.09	.6	.5
22	68	71	1.01	.05	.08	.09	.6	.5
23	68	71	1.02	.05	.07	.09	.7	.5
24	68	71	.99	.07	.14	.14	.5	.3

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 15—DARKROOM.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	68	64	.84	.07	.15	.10	.4	.7
2	68	64	1.00	.07	.16	.10	.4	.7
3	68	64	1.00	.07	.16	.10	.4	.7
4	68	65	.85	.07	.16	.11	.4	.6
5	68	65	.96	.09	.21	.15	.4	.6
6	68	64	.96	.12	.29	.20	.4	.6
7	68	64	.89	.14	.31	.22	.4	.6
8	68	64	.93	.15	.34	.22	.4	.6
9	68	64	.94	.18	.30	.23	.6	.7
10	68	65	.91	.17	.33	.17	.5	1.0
11	68	65	.94	.17	.31	.18	.5	1.0
12	68	65	.92	.17	.27	.14	.6	1.2
13	67	65	.94	.12	.19	.14	.6	.8
14	67	66	.94	.13	.15	.13	.8	1.0
15	67	66	.86	.15	.15	.13	1.0	1.1
16	66	65	.90	.15	.15	.13	1.0	1.1
17	66	65	.86	.10	.15	.11	.6	.9
18	67	64	.90	.09	.13	.10	.6	.8
19	67	64	.94	.08	.13	.10	.6	.7
20	67	64	.80	.07	.11	.10	.6	.6
21	67	64	.86	.06	.10	.10	.6	.6
22	68	64	.87	.05	.09	.09	.5	.5
23	68	64	.88	.05	.09	.09	.5	.5
24	68	64	.97	.05	.09	.09	.5	.5

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

EXPERIMENT 16—DARKROOM.

Time, hours.	Temperature, Degrees F.	Saturation Deficit %.	Standard Evaporation. Grams per hour.	Transpiration, Verbascum No. 1. Grams per Sq. Dm. per hour.	Transpiration, Verbascum No. 2. Grams per Sq. Dm. per hour.	Transpiration Verbascum No. 3. Grams per Sq. Dm. per hour.	Ratio V-1 / V-2	Ratio V-1 / V-3
1	68	64	.96	.05	.09	.08	.5	.6
2	68	64	.96	.05	.09	.08	.5	.6
3	68	64	.84	.05	.09	.08	.5	.6
4	68	64	.91	.05	.08	.07	.6	.7
5	68	64	.86	.04	.08	.08	.5	.5
6	68	64	.95	.04	.08	.08	.5	.5
7	68	60	.85	.04	.08	.08	.5	.5
8	68	60	.85	.04	.08	.07	.5	.5
9	68	62	.89	.05	.08	.07	.7	.8
10	68	62	.90	.06	.08	.07	.7	.8
11	68	63	.92	.06	.09	.08	.6	.7
12	68	64	.90	.05	.08	.08	.8	.6
13	68	65	.92	.05	.06	.08	.8	.6
14	68	65	.90	.05	.06	.07	.8	.7
15	68	66	.94	.05	.06	.07	.8	.7
16	68	66	.98	.05	.07	.07	.7	.7
17	68	66	.94	.05	.07	.07	.7	.7
18	68	66	.85	.05	.07	.06	.7	.8
19	68	66	.93	.05	.07	.06	.7	.8
20	68	66	.93	.04	.07	.06	.5	.6
21	68	66	.96	.04	.07	.06	.5	.6
22	68	65	.96	.04	.07	.06	.5	.6
23	68	64	.85	.04	.07	.06	.5	.6
24	68	64	.91	.04	.07	.06	.5	.6

NOTE: Verbascum No. 1, normal.
Verbascum No. 2, hairs removed from upper leaf surfaces.
Verbascum No. 3, hairs removed from lower leaf surfaces.

TABLE III.

SERIES I. TOTALS AND RATIOS.

	Temperature, Degrees F. Mean.	Saturation Deficit %. Mean.	Standard Evaporation. Total, Grams.	Transpiration, Verbascum. Total, Grams per Sq. Dm.	Transpiration, Nicotiana. Total, Grams per Sq. Dm.	Ratio $\frac{N}{V}$
Experiment 1—						
Night	74	51	8.00	1.24	.88	.71
Day	74	55	10.38	1.57	1.40	.89
Daily	74	53	18.38	2.81	2.28	.81
Experiment 2—						
Night	73	53	16.58	1.50	.79	.52
Day	74	54	19.71	1.31	.92	.70
Still Air	73	54	18.55	.98	.67	.68
Wind	74	53	27.74	1.83	1.04	.56
Daily	74	53	36.29	2.81	1.71	.59
Experiment 3—						
Night	66	19	2.61	1.42	.88	.62
Day	74	32	5.71	6.25	4.44	.70
Daily	70	25	8.32	7.67	5.32	.69
Experiment 4—						
Night	65	23	7.32	2.07	.67	.31
Day	71	29	8.51	5.97	4.63	.77
Still Air	71	29	3.96	3.88	2.89	.85
Wind	68	26	11.87	4.16	2.41	.57
Daily	68	26	15.83	8.04	5.30	.65

TABLE IV.

SERIES II-A. TOTALS AND RATIOS.

	Temperature, Degrees F. Mean.	Saturation Deficit %. Mean.	Standard Evaporation. Total, Grams.	Transpiration, Verbascum No. 1. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 2. Total, Grams per Sq. Dm	Transpiration, Verbascum No. 3. Total, Grams per Sq. Dm.	Ratio $\frac{V\text{-}1}{V\text{-}2}$	Ratio $\frac{V\text{-}1}{V\text{-}3}$
Experiment 5—								
Night	67	40	5.03	.93	1.14	1.33	.81	.69
Day	79	63	15.73	15.40	13.19	14.35	1.17	1.07
Daily	73	52	20.76	16.33	14.33	15.68	1.14	1.04
Experiment 6—								
Night	67	39	4.84	1.07	1.39	1.64	.77	.65
Day	81	66	20.28	18.30	20.69	27.34	.88	.68
Daily	74	53	25.12	19.37	21.08	28.98	.91	.67
Experiment 7—								
Night	68	36	4.63	1.11	1.48	1.56	.75	.71
Day	78	60	14.76	15.10	15.89	16.59	.95	.91
Daily	73	48	19.39	16.21	17.37	18.15	.93	.89
Expers. 5, 6, 7—								
Night	67	38	14.50	3.11	4.01	4.53	.77	.68
Day	79	63	50.77	48.80	49.77	58.28	.98	.83
Daily	73	51	65.27	51.91	52.78	62.81	.98	.82

TABLE V.

SERIES II-B. TOTALS AND RATIOS.

	Temperature, Degrees F. Mean.	Saturation Deficit %. Mean.	Standard Evaporation. Total, Grams.	Transpiration, Verbascum No. 1. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 2. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 3. Total, Grams per Sq. Dm.	Ratio V-1 / V-2	Ratio V-1 / V-3
Experiment 8—								
Night	67	42	6.07	1.52	2.46	2.98	.61	.51
Day	73	63	15.95	16.98	18.15	19.89	.93	.85
Daily	70	53	22.02	18.50	20.61	22.87	.89	.80
Experiment 9—								
Night	70	36	4.52	1.62	1.83	2.24	.86	.72
Day	74	46	7.71	8.40	8.65	8.68	.96	.95
Daily	72	41	12.23	10.02	10.48	10.92	.97	.93
Experiment 10—								
Night	71	38	5.20	1.30	2.07	2.96	.63	.44
Day	86	59	19.34	19.22	16.22	22.11	1.18	.87
Daily	78	49	24.54	20.52	18.29	25.07	1.12	.81
Exps. 8, 9, 10—								
Night	69	38	15.79	4.44	6.36	8.18	.69	.54
Day	74	56	43.00	44.60	43.03	50.68	1.03	.88
Daily	72	47	58.79	49.04	49.38	58.86	.99	.83

TABLE VI.

SERIES II-C. TOTALS AND RATIOS.

	Temperature, Degrees F. Mean.	Saturation Deficit %. Mean.	Standard Evaporation. Total, Grams.	Transpiration, Verbascum No. 1. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 2. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 3. Total, Grams per Sq. Dm.	Ratio V-1 / V-2	Ratio V-1 / V-3
Experiment 11—								
Night	62	48	6.80	1.68	3.05	4.40	.55	.38
Day	67	62	16.21	14.15	16.03	19.51	.88	.72
Still Air	64	55	17.94	11.65	14.52	19.11	.80	.60
Wind	70	70	5.07	4.18	4.56	4.80	.91	.87
Daily	64	55	23.01	15.83	19.08	23.91	.83	.67
Experiment 12—								
Night	59	51	12.24	2.28	2.38	2.75	.95	.82
Day	66	66	18.03	17.32	17.16	20.37	1.00	.85
Still Air	62	58	12.52	9.68	12.32	12.35	.78	.78
Wind	63	56	17.75	9.92	7.30	10.76	1.36	.56
Daily	63	58	30.27	19.60	19.62	23.11	.99	.84
Experiment 13—								
Night	68	38	3.71	1.34	1.95	2.32	.68	.57
Day	72	42	9.38	8.05	8.63	8.11	.93	.99
Still Air	70	40	8.81	6.30	6.98	7.44	.90	.84
Wind	73	41	4.28	3.09	3.60	2.99	.85	1.03
Daily	70	40	13.09	9.39	10.58	10.43	.88	.89
Exps. 11, 12, 13—								
Night	63	45	22.75	5.30	7.38	9.47	.71	.56
Day	68	56	43.62	39.52	41.82	47.99	.94	.82
Still Air	65	50	39.27	27.63	33.82	38.90	.81	.71
Wind	68	53	27.10	17.19	15.46	18.55	1.11	.92
Daily	65	51	66.37	44.82	49.28	57.45	.91	.78

TABLE VII.

SERIES II-D. TOTALS AND RATIOS.

	Temperature, Degrees F. Mean.	Saturation Deficit %. Mean.	Standard Evaporation. Total, Grams.	Transpiration, Verbascum No. 1. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 2. Total, Grams per Sq. Dm.	Transpiration, Verbascum No. 3. Total, Grams per Sq. Dm.	Ratio $\frac{V\text{-}1}{V\text{-}2}$	Ratio $\frac{V\text{-}1}{V\text{-}3}$
Experiment 14—								
Night	69	69	12.01	.82	1.70	1.83	.48	.45
Day	68	68	12.16	1.15	1.98	1.96	.58	.58
Daily	68	68	24.17	1.97	3.68	3.78	.53	.52
Experiment 15—								
Night	68	64	11.93	.85	1.74	1.33	.48	.57
Day	67	65	10.93	1.72	2.78	1.90	.61	.90
Daily	68	64	22.86	2.57	4.52	3.23	.56	.79
Experiment 16—								
Night	68	64	11.02	.53	.93	.83	.57	.63
Day	68	65	10.84	.61	.88	.87	69	.70
Daily	68	64	21.86	1.14	1.81	1.70	.63	.67
Exps. 14,15,16—								
Night	68	66	34.96	2.20	4.37	3.98	.50	.55
Day	68	66	33.93	3.40	5.64	4.73	.60	.71
Daily	68	65	68.89	5.68	10.01	8.71	.56	.65

Ohio State University,
Columbus.